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DETECTING STRUCTURAL HEAT LOSSES WITH MOBILE INFRARED
THERMOGRAPHY. PART III. SURVEY OF USA CRREL

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Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire

December 1975

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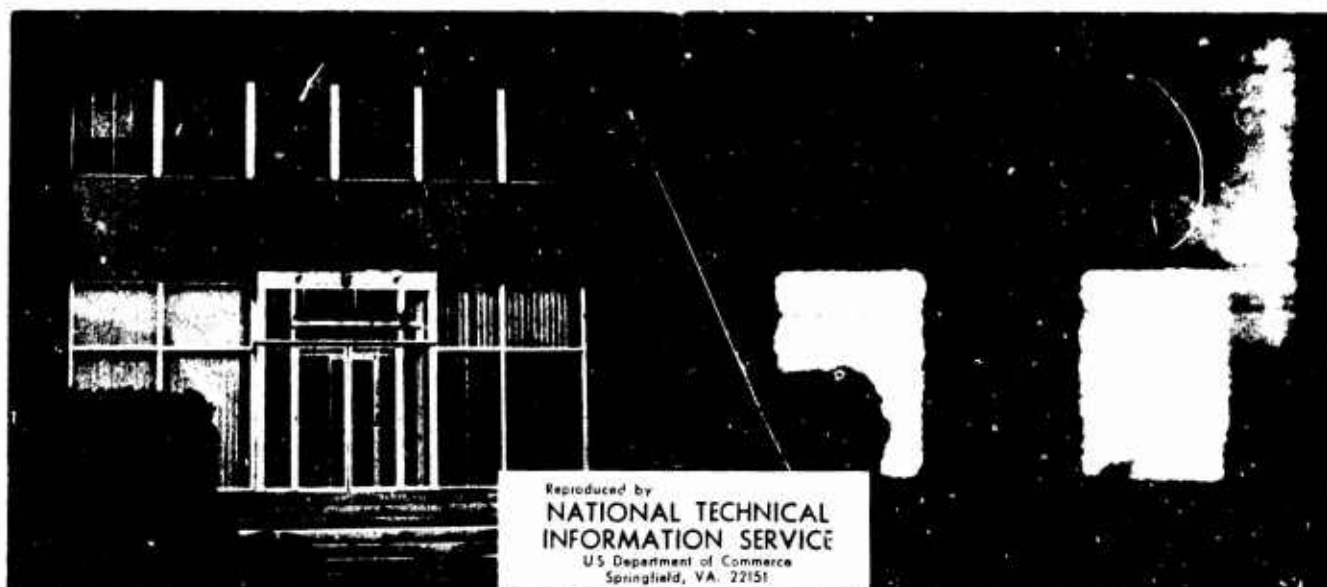
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R.H. Munis, R.H. Berger, S.J. Marshall, M.A. Bush

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Daylight, Conventional Photograph

Nighttime, Thermogram

CORPS OF ENGINEERS, U.S. ARMY
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PREFACE

This report was prepared by Dr. Richard H. Munis, Research Physicist, Roger H. Berger, Research Physicist, Stephen J. Marshall, Physical Science Technician, and Michael A. Bush, Physical Science Aid, of the Physical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory (USA CRREL). The study was conducted under DA Project 4A1611 01A91D, Task 03, In-House Laboratory Independent Research, Work Unit 174, Thermal Radiation.

This report was technically reviewed by Dr. Y.C. Yen of USA CRREL.

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DETECTING STRUCTURAL HEAT LOSSES WITH MOBILE INFRARED THERMOGRAPHY

Part III - Survey of USACRREL

by

R.H. Munis, R.H. Berger, S.J. Marshall and M.A. Bush

Introduction

During the winter of 1973-74, the U.S. Army Cold Regions Research and Engineering Laboratory (USACRREL) developed a survey technique to measure heat losses using an infrared scanner. A mobile infrared scanner system was leased from the Barnes Engineering Company of Stamford, Connecticut, and heat loss surveys were made of USACRREL, Pease Air Force Base and the Dartmouth College campus. Part I of USACRREL report based on these surveys (Munis et al. 1974)* gives a description of the technique, while Part II (Munis et al. 1975)† gives the results of the survey of Pease Air Force Base, Portsmouth, New Hampshire. This report (Part III) deals only with the results obtained from the survey of the USACRREL building at Hanover, New Hampshire, during the months of February and March of 1974.

The objective of this survey was to pinpoint potential locations of excessive heat losses in the USACRREL building. The final report in this series (Part IV) will discuss quantitative results derived from the controlled experiments (using thermography) which were done at the USACRREL building and at the Dartmouth College campus.

Results and discussion

The discussion in Part II of *Detecting Structural Heat Losses with Mobile Infrared Thermography* (Munis et al. 1975) regarding "apparent heat loss," emissivity corrections and positioning of the infrared scanner is also applicable to the results of this survey. However, since the outside surface of most of the USACRREL building is a brick facing, it was generally not necessary to consider an emissivity correction when comparing the heat flow rate at one location with that at another location.

Figure 1 shows the thermogram and regular picture of the northeast side of the USACRREL building. The thermogram was taken on 13 February 1974 at approximately 2200 hours. The ambient temperature was 36°F and the wind (as measured at a station located at USACRREL) was from the south at 2 mph. The large white spot between the two rows of windows shows heat flowing out of an open vent. An interesting qualitative comparison of the relative heat flow (white to black contrast) from the five second floor windows located at the east corner of the building can be noted. Windows 1-3 are fitted with a pair of heavy drapes with a separate liner between the windows

* Munis, R.H., R.H. Berger, S.J. Marshall and M.A. Bush (1974) Detecting structural heat losses with mobile infrared thermography, Part I - Description of technique. U.S. Army Cold Regions Research and Engineering Laboratory (USACRREL) Research Report 326. ADA001549.

† Munis, R.H., R.H. Berger, S.J. Marshall and M.A. Bush (1975) Detecting structural heat losses with mobile infrared thermography, Part II - Survey of Pease Air Force Base, Portsmouth, New Hampshire. USACRREL Research Report 338. ADA012117.

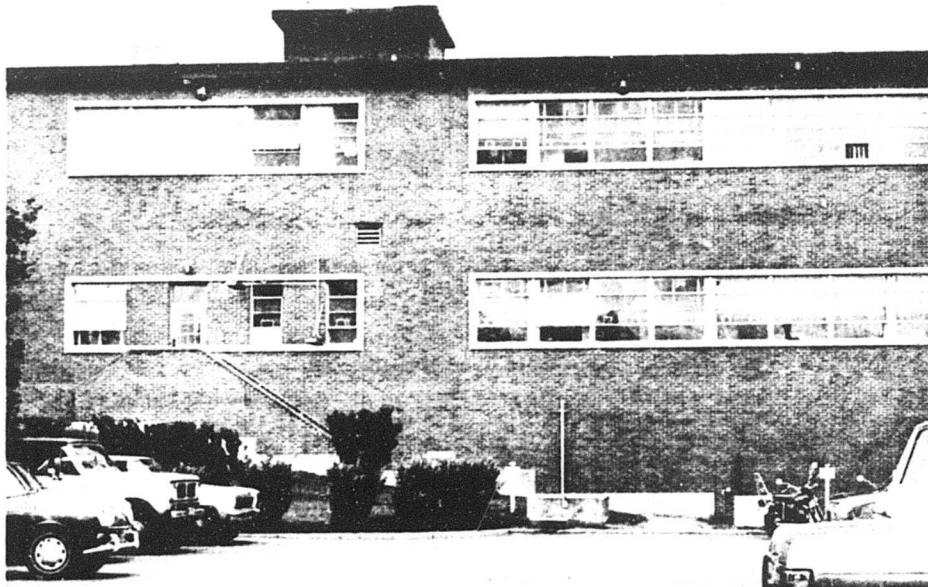
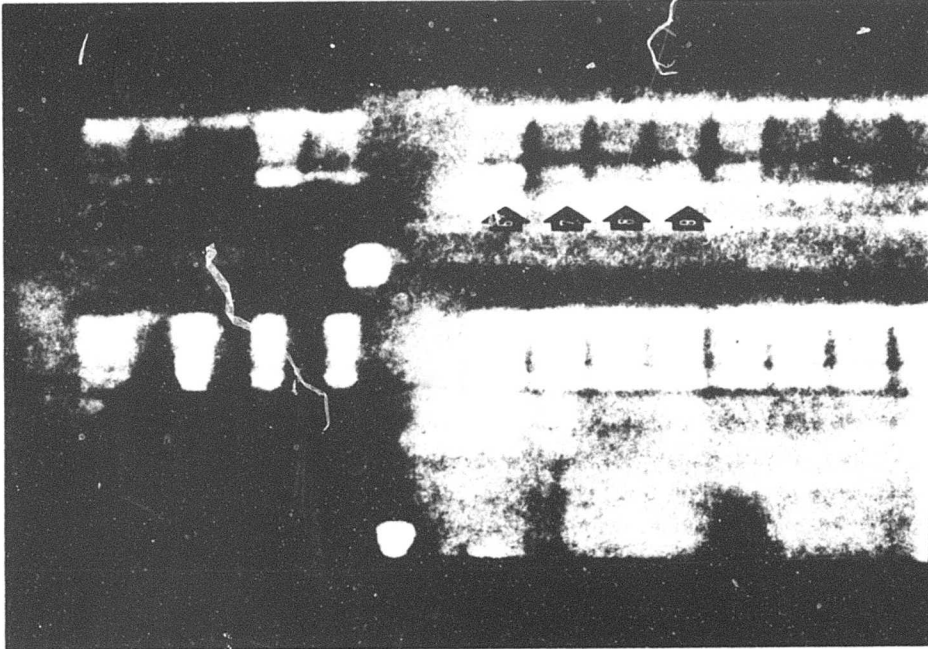


Figure 1. Northeast side of USACRREL building. Windows are numbered to distinguish differences in heat loss. (See text.)

and the drapes, while window 6 has venetian blinds (pulled down), and windows 4 and 5 have neither blinds nor drapes. Notice that there is relatively more heat (whiter contrast) emanating from the top panes of windows 4-6 than there is from the top panes of windows 1-3. The remaining windows (all fitted with venetian blinds) on the second floor show this same pattern, indicating a rather uniform stratification of warm air near the ceiling in all the rooms in which these windows are situated. While this stratification is somewhat evident at the top panes of windows 1-3, it is obvious that the



Figure 2. Typical window at USACRREL.

drrape-liner combination does retard a noticeable amount of heat in comparison with the venetian blinds. However, in comparing windows 4 and 5 with those fitted with venetian blinds, it is obvious that the venetian blinds retard little if any of this layer of warm air near the ceiling from reaching the window surface.

Careful observation of window 6 shows heat escaping all along the left side of the window (top to bottom); this seems to indicate that there is a heat leak along the glass to metal casement joint or along the mortar to metal casement joint. Figure 2 shows a typical window at the USACRREL building. It is interesting to note that window 6 is the only one of the 24 windows shown in the Figure 1 thermogram that has a rather bad heat leak around the metal casement, indicating a direct flow of air from inside to outside. The top horizontal casement member on all the windows seems to be warmer than the lower casement member and the lower part of the vertical members, indicating that conductivity through these top horizontal members is being generated by the temperature gradient between this layer of warm air near the ceiling and the outside air.

The large bright area beneath window 6 is the heat from the radiator which has reached the outside surface of the building. The bright zone beneath windows 7, 8 and 9 indicates the presence of a radiator at that location. The bright spot beneath the window directly below window 6 likewise indicates the presence of a radiator. Also, the bright region below and to the left of this window indicates heat being transmitted through the wall at that location. At the edge of this bright region (arrows) is located (inside of the building) a wall separating the two rooms.

The relatively bright appearance of the lower row of windows (compared with the top row) would perhaps lead one to believe that abnormal heat leakage is occurring through these windows. However, the real reason for this high apparent heat loss is that during the survey of the USACRREL building the first floor room temperatures were consistently significantly higher than the second floor room temperatures. The Figure 1 thermogram illustrates one of several reasons that the



Figure 3. Main entrance of USACRREL building. Black horizontal arrows point to south-facing slate wall. White horizontal arrows point to east-facing slate wall. Each of six vertical arrows points to window with an installed storm sash.

structural thermographic analysis must be done very carefully and with as much supporting data as can be obtained about any building.

Figure 3 shows the thermogram and regular picture of the front entrance of the USACRREL building. The most obvious heat loss (two bright rectangles) in this thermogram is through the single panes of glass in the two large windows of the lobby. Again it must be emphasized that a significant amount of this heat loss is due to the higher than normal lobby temperature which was recorded on the evening that the thermogram was taken. However, as can be seen from the dark zone between the two bright rectangles, there is a distinct advantage in having a foyer (which can act as an air lock) leading into a building. Because of the insulating value of the airspace in the foyer, the heat flow at this location is approximately only one-fourth of that occurring through each large window.



Figure 4. South side of USACRREL building. Thermogram taken at 2100 hours, 13 February 1974. Arrows point to south-facing slate wall.



Figure 5. South side of USA CRREL building. Thermogram taken at 1600 hours, 21 February 1974.

In the same manner, the added value of storm windows is illustrated in Figure 3 (six vertical arrows). Each arrow points approximately to the bottom of a window which has a storm sash installed. Comparison of the white-black contrast at this location with that observed at the foyer indicates that the insulation effectiveness of a storm window is comparable to that of the foyer.

The large bright area (horizontal black arrows) to the right and above the lobby windows illustrates another important point regarding thermographic analysis. The black arrows point to the relatively warm south-facing slate wall of the auditorium-library extension, while the vertical white arrows

point to the cool east-facing slate wall. One might immediately conclude that all of this heat is escaping through the wall from the inside. However, several factors must be taken into consideration before a final conclusion can be reached. When this thermogram was taken (2100 hours), the air temperature was 36°F. Although the sky had been overcast part of the day, there had been a few hours of sunshine during both morning and afternoon. The combination of solar heating of the slate, an abnormally warm air temperature, the protected exposure of the south-facing wall, and a low wind velocity (southerly at 2 mph) serves to explain why the south-facing wall of this extension is warmer than the east-facing wall.

Additional evidence of the effect of solar heating can be seen by comparing the white-black contrast of Figure 4 (south exposure of USACRREL) with that of Figure 1 (northeast exposure). Both thermograms were taken about an hour apart. As can be seen from Figure 4, the entire brick wall is white, indicating the rather uniform retention (and decay) of solar radiation. Some of the radiation from the south-facing slate wall of the library-auditorium extension can be seen in this thermogram (arrow). Figure 5 shows a thermogram of the south exposure taken at 1600 hours on 21 February 1974. The air temperature was 46°F and the wind velocity was northwesterly at 10 mph at the time that this thermogram was taken. A considerable amount of incoming solar radiation during

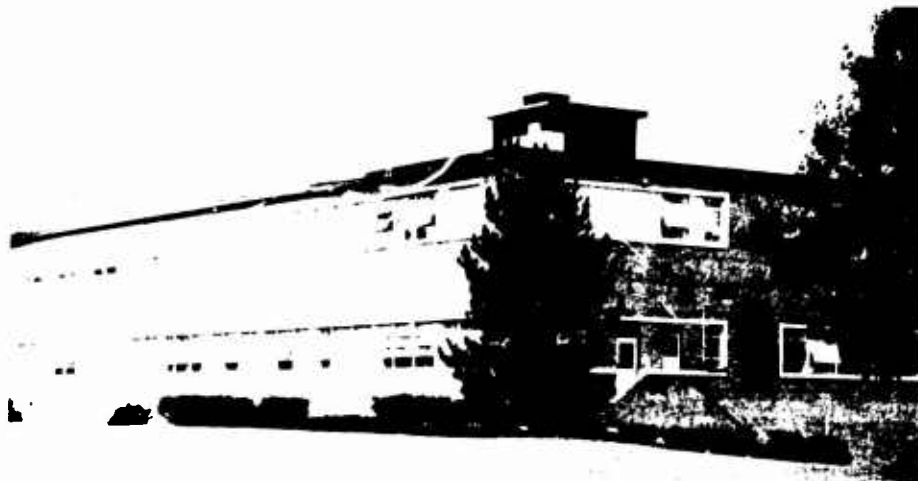


Figure 6. Northeast corner of USACRREL building. Arrows point to wall surface heated by radiators.

the day was responsible for the "white" appearance of the building. Comparison of the thermogram in Figure 5 with that in Figure 4 (even though taken on different days) illustrates the point that adequate time must be allowed for the decay of solar radiation before a true heat loss evaluation can be made.

Figure 6 shows the thermogram and regular picture of the northeast corner of the building. Arrows point to locations of outside wall surface heated by radiators mounted on the wall directly behind these heated areas.

Figure 7 shows the thermogram and regular picture of the northwest corner of the cafeteria. One noticeable path of heat loss is through the metal window frames (vertical and horizontal white lines). Since metal has a relatively low emissivity, these frames should appear dark (cool) if there is no heat loss through them. However, since there is no insulation between the inside and outside frames, conductivity carries the heat directly to the outside surface where it is lost to the air through radiation and convection. The horizontal black arrows point to insulated porcelain-enamel panels

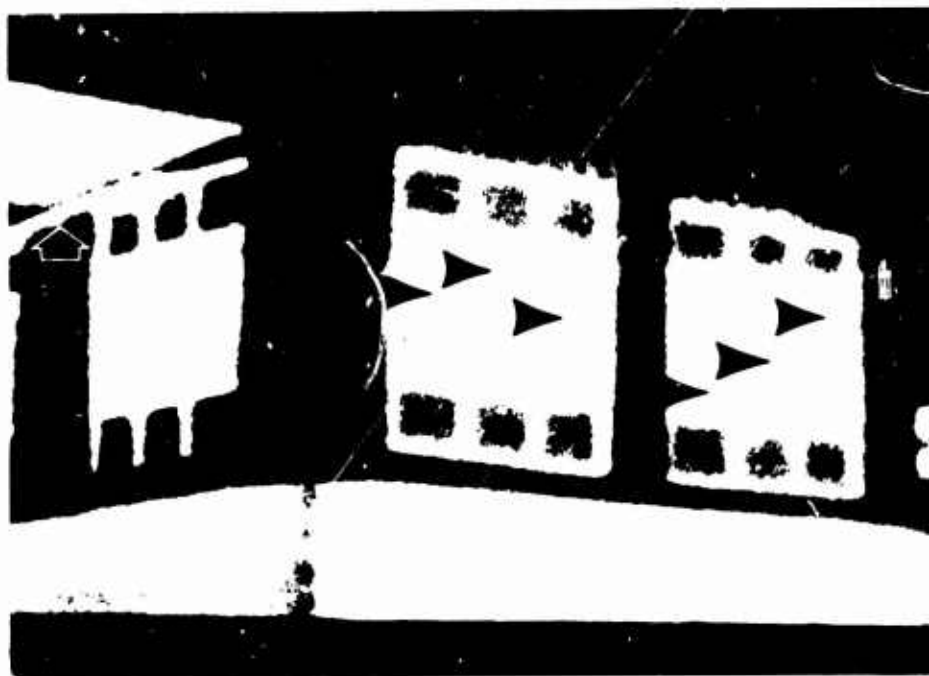


Figure 7. Northwest corner of cafeteria addition (metal building). Black arrows point to insulated porcelain-enamel panels. White arrow points to location of heat leak at roof-wall joint of metal building.

($1\frac{5}{8}$ in. thick) consisting of a sandwich fabrication. Notice that the surfaces of these panels are considerably cooler than the surfaces of the window glass (white rectangles) in spite of the fact that the drapes were drawn at the time this thermogram was taken. However, since these drapes are translucent and have no liners, their insulating effectiveness is considerably inferior to that of the drape-liner combination used in the windows shown in Figure 1.

Figure 8 shows the thermogram and regular picture of the west side of the north-facing wall. The white zone (lower arrows) underneath two of the cafeteria kitchen windows indicates an excessive loss of heat at that location, attributed to a tank of hot water kept at 200°F and a section of the

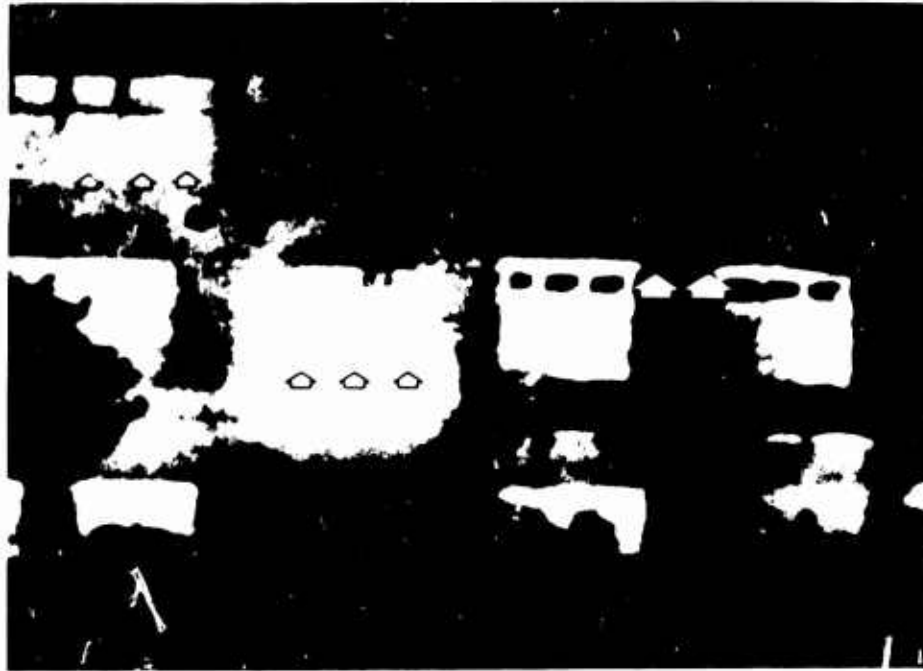


Figure 8. West side of north-facing wall. Lower arrows point to heat escaping by conduction through wall of the cafeteria kitchen. Upper arrows point to heat escaping by conduction through wall of second floor office. White arrows point to location of heat leak (see Fig. 7).

room heating unit. The white zone to the upper left (upper arrows) indicates that this radiator is on and that a significant amount of the radiated heat is being conducted directly through the wall. The faint white line (white arrows) between the two large north dining area windows indicates a possible heat leak at the roof-wall joint of this metal building. Another view of this location can be seen in Figure 7 (arrow at extreme left side of thermogram).

Conclusions

The heat loss survey of the USACRREL building showed a number of locations where heat was being lost that could be conserved if corrective actions were taken. Since almost all of the windows are single panes, corrective action needed to be taken to provide an additional insulating layer over the single panes. (As a result of this research it was decided that the most cost-effective approach in the interim was to put sheets of plastic over the inside window frames on the north side of the building.) The thermographic analysis also showed that in a number of places heat from the wall-mounted radiators was being lost by conduction through the masonry wall. This situation could be corrected by placing metal reflectors behind the radiators (but insulated from the wall).

Finally, this study showed that thermographic analysis must be done very carefully and with as much supporting data as possible to avoid the possibility of analyzing a building as having an actual heat loss when in fact the heat loss might be due to nothing more than solar radiation decay from the building walls.